in September, in October Mr. Clark substituted the name *stella* for *tenuis* as the latter is preoccupied. Now are we to understand that Mr. Clark has concluded his three names refer to a single species? If so the description of *tenuis* and *ciliata* as distinct species was, to say the least, hasty. Again, under Compsometra, we find the following bit of evidence of haste in preparation: certain characters "distinguish this species at once. The two species at present known are," etc. Evidently the first "species" should read "genus." Under Isometra, Mr. Clark says that the name *challengeri* which he bestowed on an Antedon in 1907 is a synonym because it was given "before its relation to *angustipinna* was detected." Under Pentametrocrinus attention is called to an important morphological feature of certain species of Eudiocrinus, which "seems to have escaped the notice of all subsequent workers," and yet Mr. Clark himself published, less than a year ago, quite a paper on Eudiocrinus, with description of a new species and an annotated list of all previously known ones. Finally, in concluding his paper, Mr. Clark says, "The genera of free crinoids belonging to the Comatulida may be grouped as follows," and he then gives eight families with their various genera. But we fail to find the Atelecrinidæ or the genus Atelecrinus mentioned, and we can only guess whether the genus is considered synonymous with one of those given (which hardly seems possible) or is omitted through carelessness. Now while it is true that none of these slips is serious, Mr. Clark has not hesitated to criticize other writers for very similar blunders, and their presence in his work necessarily affects our estimate of its reliability. It is of the greatest importance, if the mantle of Carpenter is to rest becomingly on his shoulders, that in his future work, Mr. Clark reveal a greater patience, a more controlled enthusiasm and a more painstaking care in the preparation of his results for publication.

H. L. C.

ANIMAL BEHAVIOR.

Recent Work on the Behavior of Higher Animals.—The members of the genus Mus—the rats and mice—seem in a fair way to become the classic animals for comparative psychology, as the frog has long been for physiology. The work of the Harvard school, examined in our last review, dealt largely with these animals. The recent work of the Chicago laboratory is concentrated even more precisely on the white rat.

In his earlier work on "Animal Education," Watson had made such a general study of the behavior of the white rat as to give a survey of the problems and methods for future work. He and his collaborators have now undertaken a well-considered campaign of intensive investigation in the different phases of the rat's behavior.

The matter selected for first attack is "the determination of the relative importance of the several sensations of a given animal in its adjustment to its environment." What senses does the rat use in finding its way about and what part does each sense play? To this is devoted the main recent work from the Chicago laboratory.[1]

Watson finds, as Yerkes did with the dancing mouse, that the rat makes comparatively little use of senses that we are accustomed to think of as the all-important ones. His conclusion that sight, touch, hearing and smell play little, if any, part in the rat's finding its way about may almost receive the usual reportorial characterization of scientific results as "startling."

The method of work was to place the rat at the entrance of the complicated "Hampton Court" maze, with its many passageways and blind alleys, and allow it to find its way to the central compartment, where food had been placed. This was repeated many times, till the correct path was completely learned; many different rats were used, and a thorough study was made of the rat's method of finding its way. The questions are essentially, (1) what senses does the rat use in learning the correct path; (2) what senses does it use in following the correct path after it is learned?

To answer these questions, one or more senses were excluded, in different specimens, either by operative procedure or by other methods. The following extraordinary results were reached:

1. Blinded rats, or those studied in complete darkness, learn the path as quickly and follow it as readily as do those that can see. Even if the path is learned in the light, blindness causes no disturbance in later following it. (One rat formed an exception, finding its way in the dark only with the greatest difficulty.)

2. Rats deprived of smell and of hearing do not differ from normal ones in learning and following the correct path. This is true even when these rats *are likewise blinded.*

[1] Watson, J. B. Kinæsthetic and Organic Sensations: their Rôle in the Reactions of the White Rat to the Maze. *The Psychological Review,* Monograph Supplement, Vol. 8, No. 2, 1907, 100 pages.

3. Removal of the long vibrissæ or "feelers" on the face at first disturbed the rats greatly. But if, before testing them with the maze, the rats were allowed forty-eight hours to become accustomed to the loss of the vibrissæ, then they threaded the maze as readily as did normal rats. This was true even if these same rats were blind or without smell.

4. Altering the temperature conditions, changing the air currents in the maze, or making the feet insensitive does not disturb the rats, so that the corresponding senses seem to play no part in the behavior.

5. The evidence is strong that taste plays no part in the matter.

Apparently then we can exclude sight, touch, smell, hearing, taste and the temperature sense as factors of any importance in finding the way through the labyrinth. How then *does* the rat find its way?

Evidently the rat relies for its guidance mainly on the complex of inner sensations due to its own movements, the amount of effort it has put forth, and the like; the "kinæsthetic and organic sensations." In threading the maze, the animal learns how much effort it is to put forth going in a certain direction, which way and how much it is then to turn, how much effort to put forth in the new direction, which way to turn again, etc. It finally knows the entire path as a combination of such efforts and turns. The behavior of the rat is somewhat like that of a person who may, in the dark, walk about a house with which he is familiar, threading his way among tables and chairs, without touching them. But in man this involves many memory images of the various objects and their relative positions and distances. In the rat such images evidently play little if any part; it is mainly a matter of amount of effort, direction of turn, and the like. Watson is inclined to conclude that the rat has no such images; that the purely intraorganic sensations account for the entire behavior; that the rat uses in threading the maze no sense data from the outside, either past or present.

If this is true, then if the trained rat could be started at the entrance of the maze so as to get the proper "cue" at the beginning, and then *the entire maze lifted from the floor, so as to leave a clear space to the food in the center, the rat ought nevertheless to follow the same complex path that it follows when the walls of the maze are present.* Would this occur? Could not the experiment be tried?

While it appears conceivable that the running of the maze, after it is learned could be exclusively a matter of the inner sensations, so that the rat might follow the path even if the maze were absent, it is extremely difficult to see how this could be the case with the first learning of the maze. Our proposed experiment of removing all source of "extraorganic" sensation by doing away with the walls of the maze seems a *reductio ad absurdum;* the rat certainly would not learn the typical maze path under such conditions. How does the rat *learn* that it must put forth so much effort in a certain direction, then turn in a certain way? It would seem that for this, certain data from outside,—due either to feeling the wall with vibrissæ, or running squarely against it, or the like—are necessary. Even when the rat runs full tilt against a wall, that gives some sort of an extrinsic sensation that would seem to require consideration.

This is a point which the author does not make clear, though he seems to argue decidedly that it is possible to explain the entire behavior, both in learning and in finding the way after it has been learned, from the purely inner sensations. Does he perhaps hold that the only effect sensed by the rat, when it runs against a wall, is one of restraint, of prevention of further effort in that direction? Such a view would seem possible, if at all, only for actual collision at full speed, while cases where the rat merely feels the wall with its vibrissæ seem hardly open to this interpretation. It would have been helpful to certain readers if the author had so far recognized their obtuseness as to take up this point explicitly. In passing it may be remarked that the entire paper is written in a curiously confused and careless manner, as if it were a first draft which the author had not found time to revise. So thorough and important an investigation deserved better treatment.

A further development of the work set forth in the paper of Watson is presented in a later paper by Carr and Watson.[2] If the rat's method of threading the maze is merely to go a certain distance (as measured by the amount of effort put forth) then to turn in a certain direction, etc., without any data from outside itself, then evidently it would be greatly disturbed by altering the lengths and proportions of the passageways. Or if it is set down not at the entrance to the maze, but in the middle

[2] Carr, Harvey, and Watson, J. B. Orientation in the White Rat. *Journ. Comp. Neurol. and Psychol.,* 1908, 18, 27–44.

of one of the passages, of course a different combination of movements will be required to reach the center; a combination which it will not have learned, so that confusion would result. On the other hand, if the rat recognizes the correct turns, etc., by sight or other extraorganic senses, then less confusion need result from the changes mentioned.

The paper of Carr and Watson is an account of the behavior of the rat when the alterations above mentioned are made. When the trained rat is placed, not at the entrance of the maze, but in one of the passages, it appears confused, wanders about, then suddenly gets a "cue," and runs directly along the correct pathway to the center. The authors argue that the animal gets this cue through the intraorganic sensations. The rat wanders till it finds that it puts forth a certain amount of effort in a certain direction and then turns in a certain direction, etc.; this combination is familiar, so that the correct movements for the rest of the course are at once "set off" by it.

When certain passages of the maze were lengthened or shortened after the animal had learned the correct path, this caused precisely such disturbances as would be expected if the kinesthetic sensations are the fundamental ones. If a passage is made shorter than before, the rat runs full tilt against its end, even though this would appear to be "in plain sight." If a passage is made longer, the rat tries to turn when it has gone the usual distance; it thus runs against the side wall. If a blind passage now opens at a distance corresponding to that of a former correct turn, the rat runs into the blind passage.

After many trials in the altered maze the rat finally learns to run through it as readily and correctly as before. This result is reached after many experiences of running into ends, "nosing" along side walls, trying to turn where there is no passageway, and the like. The reader is inclined to see here an excellent opportunity for study of the transformation of cues from outer sense data into kinesthetic cues. But again the authors argue that the whole is purely a matter of the inner sensations. If they would explain clearly just how the animal gets its kinesthetic cues without aid from outer sense data; how it learns without running into the end of a passage that it must put forth only so much energy in a certain direction; or if they would demonstrate that bumping into walls, nosing along passages, and the like, gives no extraorganic sensations of any consequence,

the reader would appreciate better their argument as to the *exclusive* rôle of the inner senses. One is slightly inclined to feel that the authors are making the common mistake of weakening the effect of a demonstration of the unsuspected great importance of a certain factor, by endeavoring to maintain that it is the *only* factor.

Another factor in rat behavior is dealt with in the paper of Slonaker.[3] Watson in his earlier work had found that young rats (25 to 30 days old) learn certain operations more quickly than do the adults, and this appeared to be due to the fact that the young were more active. They tried, in a short time, all sorts of movements, and were therefore likely to hit quickly upon the "right" ones. Slonaker makes a careful study of the comparative amounts of activity in rats of different ages, in order to see how far this is correlated with the quickness of learning. A revolving cage was used, of such a character that the activity of the rats was automatically recorded. One such experiment, with several rats, lasted 25 days; another 57; another 60. It was found that, while there are great differences in individuals, both the very young rats and the old ones (age about a year) were comparatively inactive; the period of greatest activity falls in the age between 87 and 120 days. No close relation was evident between these results and those of Watson on quickness in learning.

All together, the work of the Chicago laboratory has of late been directed with unusual precision on a well-defined single line of research. And hand in hand with this work on behavior have gone studies on the nervous system, growth and life history of the rat, many results of which have been published from the neurological laboratory. Such a unified and intensive series of investigations may well serve as a model of the best method for making solid and permanent advance in comparative psychology.

H. S. JENNINGS.

[3] Slonaker, J. R. The Normal Activity of the White Rat at Different Ages. *Journ. Comp. Neurol. and Psychol.*, 17, 1907, pp. 342–359.

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